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Supplementary File

Impedance Threshold Device Combined With High-Quality Cardiopulmonary Resuscitation Improves Survival With Favorable Neurological Function After Witnessed Out-of-Hospital Cardiac Arrest

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Supplementary File 1

Methods

The concept of the impedance threshold device (ITD) was first described in 1995.[S1] The device has undergone multiple changes since then and has been studied in multiple animal and human trials as described in a recent review article.[S2]

The core functional elements of the ITD used in the Resuscitation Outcomes Consortium (ROC) study were as follows and shown in **Figure S1**.

1. A conduit through which ventilation was provided without significant resistance from a positive pressure source (eg, resuscitator bag or ventilator).
2. An atmospheric sensor diaphragm that impeded airflow into the lungs when the pressure inside the chest is less than the atmosphere, which occurs during the chest recoil phase of cardiopulmonary resuscitation (CPR), gasping, or with spontaneous breathing.
3. A safety check valve (set to −16 cm H_2O in the ROC study) that allowed respiratory gases to enter the lungs when the check valve opened.
4. Two connector ports, one fitting on a standard endotracheal tube, face mask fitting or supraglottic airway, and the other fitting onto a resuscitator bag or mechanical ventilator.
5. A timing light that flashed 10 times per min to provide the rescuer with a visual cue of the correct ventilation rate.
6. Opaque yellow coloration to blind the rescuers to whether the device was active and functional or a sham (placebo).

During conventional or standard CPR, as well as during active compression-decompression (ACD) CPR, the ITD enhances circulation to the heart and the brain when CPR is performed

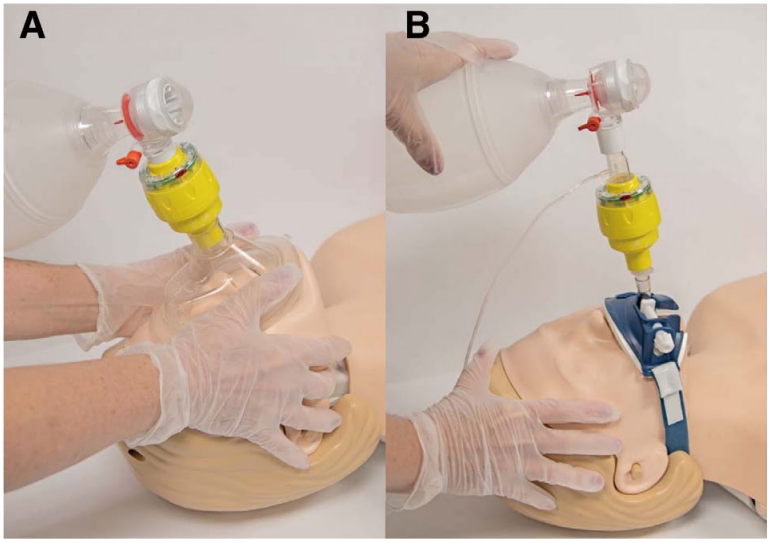

Figure S1. How to use an impedance threshold device (ITD). (**A**) When using the ITD with a facemask during Basic Life Support, rescue personnel should use a 2-handed approach to managing the airway, as recommended by the American Heart Association Guidelines. The ITD only works well when there is a continuous tight seal between the facemask and the skin. (**B**) The ITD is also easily attached to an endotracheal tube.

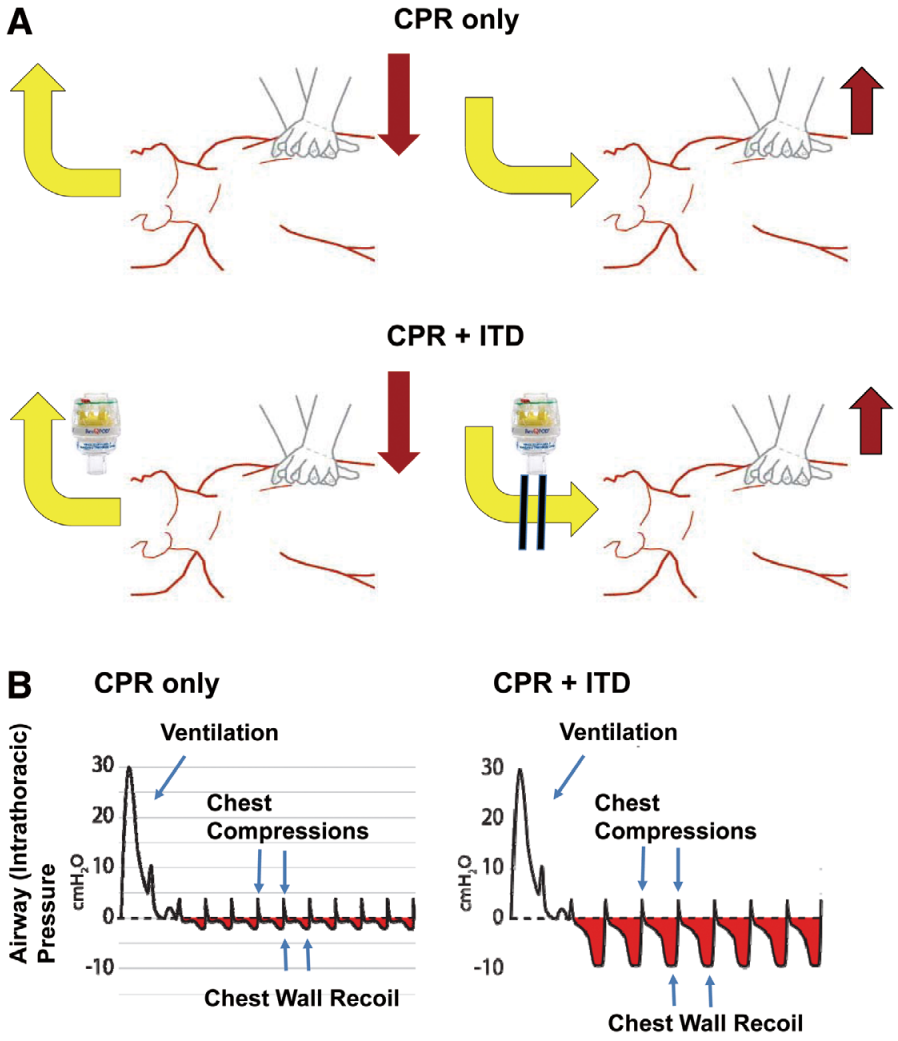

Figure S2. Mechanophysiology of cardiopulmonary resuscitation (CPR) with an impedance threshold device (ITD). (**A**) Schematic representation of the function of ITD during the chest compression and recoil phases during CPR. (**B**) Comparison of airway (intrathoracic) pressure during CPR only (**Left**) and CPR+ITD (**Right**). Chest compression increases the intrathoracic pressure, causes forward blood flow, and forces respiratory gases out of the lungs. Note that minimal expiratory resistance is present during CPR only as well as with CPR+ITD. Greater negative intrathoracic pressure during the recoil phase in CPR+ITD than in CPR only increases the preload more, resulting in increased cardiac output, whereas that lowers intracranial pressure more, leading to increased cerebral perfusion.

correctly. The known physiological effects of the ITD are as follows and as shown in **Figure S2**.

1. During the chest recoil phase of CPR the device limits respiratory gases from entering the lungs, thus enhancing the negative intrathoracic pressure and generating a vacuum within the thorax that draws more venous blood back to the heart from the brain and other extrathoracic compartments. The physiologic benefits of this vacuum include enhancing cardiac preload and lowering intracranial pressure during the recoil phase. This results in greater cardiac output during the next compression phase and less resistance to forward brain flow.
2. The ITD allows respiratory gases to leave the lungs during each chest compression but prevents gases from reentering during the recoil phase. With successive compressions there is less and less respiratory gas in the lungs, which makes it easier for blood to refill the lungs during the recoil phase until the next positive pressure is delivered.
3. CPR with the ITD mimics the effect of gasping, which lowers intrathoracic pressures, enhances venous return, and lowers intracranial pressure.

References

S1. Lurie KG, Coffeen P, Shultz J, McKnite S, Detloff B, Mulligan K. Improving active compression-decompression cardiopulmonary resuscitation with an inspiratory impedance valve. *Circulation* 1995; **91:** 1629–1632.

S2. Lurie KG, Nemergut EC, Yannopoulos D, Sweeney M. The physiology of cardiopulmonary resuscitation. *Anesth Analg* 2016; **122:** 767–783.